Award Number: W81XWH-09-2-0190

TITLE: “Natural History of Multi-Drug Resistant Organisms in a New Military Medical Facility”

PRINCIPAL INVESTIGATOR: COL Emil Lesho

CONTRACTING ORGANIZATION: The Geneva Foundation
Tacoma, WA 98402

REPORT DATE: December 2013

TYPE OF REPORT: Final

PREPARED FOR: U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

DISTRIBUTION STATEMENT: Approved for public release; distribution unlimited

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
December 2013	Final	30Sep2009 – 29Sep2013

4. TITLE AND SUBTITLE
"Natural History of Multi-Drug Resistant Organisms in a New Military Medical Facility"

5a. CONTRACT NUMBER

5b. GRANT NUMBER
W81XWH-09-2-0190

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
COL Emil Lesho

EMAIL ADRESS:
Emil.p.lesho.mil@mail.mil

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

The Geneva Foundation
917 Pacific Ave., Ste. 600
Tacoma, WA 98402

8. PERFORMING ORGANIZATION REPORT

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S Army Medical Research and Materiel Command
Fort Detrick, MD 21702-5012

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
A unique approach combines several platforms to assess BOTH the thoroughness AND the effectiveness of room cleaning in a newly constructed and opened hospital (FBCH). The former is accomplished using CDC developed protocols and an invisible dye-ultraviolet light system for sampling 17 high-touch surfaces (i.e. call buttons, bathroom hand rails, IV pumps/poles) before and after terminal room cleaning. This is incorporated into a web-based reporting and feedback system. Effectiveness of cleaning is accomplished using BOTH standard culture- based techniques AND molecular techniques - a real-time, species specific multiplex assay we have developed. Results & feedback are provided to hospital cleaning and infection control staff.

15. SUBJECT TERMS none provided

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18.NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** USAMRMC
a. REPORT U	**b. ABSTRACT** U	**c. THIS PAGE** U	UU	31	**19b. TELEPHONE NUMBER** *(include area code)*

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

Table of Contents

INTRODUCTION

The key role that the inanimate hospital environment plays in the transmission of multidrug-resistant Gram-negative bacteria and methicillin-resistant Staphylococcus aureus (MDRO) is increasingly recognized. In fact, some experts argued at the Spring 2013 conference of the Society of Healthcare Epidemiologists of America that environmental hygiene is as, if not more, important than hand hygiene.

Although clinically relevant bacteria persist on environmental surfaces for weeks and months, important Gram-negatives such as *E. coli* and *Klebsiella* spp. may be harder to isolate with culture-based methods, due to their lower viability and bio-burden in the environment. Such viable, but unculturable, bacteria may be harder to detect and therefore under-reported. Furthermore, such bacteria have been recently shown to take up even short damaged DNA, ubiquitous in most environments, and incorporate it into their chromosomes. This DNA may be a previously unrecognized driver of bacterial evolution or resistance and has implications for environmental hygiene.

Differences in hospital design, sometimes referred to as the built environment, are also receiving more attention. Evidence-based design is the concept of improving patient, staff and organizational outcomes through hospital design based on the presupposition that various aspects of the built environment, such as the design of patient rooms, natural lighting, views of nature, and state of the art technology, have been shown to have positive effects on patient recovery and staff satisfaction and retention. In 2009, the Assistant Secretary of Health Affairs for the DoD mandated that construction of new military health care facilities use evidence-based design.

Although many studies of environmental surveillance and cleaning methods have been published, we could find no reports conducted at a newly opened hospital constructed with evidence-based design, using three methods in parallel to assess both the thoroughness and effectiveness of cleaning and the impact of a single brief intervention on cleaning efficacy. The three methods include: a) an invisible liquid marking and reporting system DAZO® and Encomapss®; b) standard cultures; and c) a multispecies polymerase chain reaction assay.

A single, brief intervention, when conducted by healthcare providers during routine appointments, has been shown to be effective in altering behavior such as weight loss and smoking cessation. Often, the only type of educational intervention that logistics, resources or time constraints will permit is a single, brief episode. Finally, even if multiple educational interventions are offered, some staff may only receive one due to turn-over or other factors.

BODY

Objectives

Our objectives were to assess the following in a newly opened community hospital constructed with evidenced-based design: 1) the level of environmental contamination with target organisms from before opening to 16 months thereafter; 2) the thoroughness and effectiveness of terminal room cleaning; 3) the impact on number 2 of a single brief educational intervention conducted midway through the surveillance period; 4) the genetic relatedness of any multidrug-resistant (MDR) target organism isolated from the environment to those isolated from clinical infections in in-patients at the facility; and 5) the correlation between target organisms (both MDR and non-MDR) isolated from the built environment and those isolated from clinical infections from inpatients at the facility.

Methods

The study was undertaken as a quality improvement, patient safety project. It was also approved by the Institutional Review Board of Walter Reed Army Institute of Research (protocol number 1761) and the Department of Clinical Research at Fort Belvoir Community Hospital (FBCH).

FBCH is a newly constructed, 120 bed, evidenced-based design facility in northeastern Virginia. It opened in September 2011 and has 10 operating rooms, a medical-surgical intensive care unit, a telemetry unit, separate medical and surgical wards, and pediatrics and maternity wards. Bed rail and mattress surfaces in the intensive unit and telemetry unit are copper impregnated.

We defined a target organism as any of the following: *Acinetobacter baumannii, Acinetobacter baumannii calcoaceticus complex; E. coli; Enterobacter spp; Pseudomonas aeruginosa,* methicillin-resistant *Staphylococcus aureus (MRSA); Klebsiella pneumoniea; and Clostridium difficile*. Multidrug-resistance (MDR) was defined as described by Magiorakos et. al. in 2012.

Room Surveillance and Educational Intervention

This surveillance was not conducted in response to an outbreak. Surveillance was prospectively conducted from August 2011 to and including January 2013, beginning one month before patients and healthcare staff arrived at the hospital (September 2011) and continuing for 16 months thereafter. After patients were discharged, but before terminal cleaning was performed in their room, 17-high touch surfaces were marked with an invisible liquid dye and sampled for 20 seconds using a rayon tipped swab pre-moistened with nutrient transport media. After terminal cleaning, the presence or absence of the dye was assessed with an ultraviolet light and recorded using a hand-held device (Encompass monitoring system). The same surfaces were re-sampled using another swab for each surface in the same manner.

We sampled each surface with a separate swab, because in a pre-study validation of our specimen processing methods, a composite swab frequently failed to detect bacteria that were known to be present from spiked research surfaces and from surfaces in a hospital. Therefore each time a single room was surveilled, 34 specimens were generated (17 before and 17 after specimens).

Sampling took place at least once a month for 17 consecutive months. Sampling was conducted clandestinely during the first 7 months to minimize the Hawthorn effect. During the seventh month, we presented the results to the environmental services (EVS) department during an educational event using the recommended standardized CDC format. For the next six months the EVS staff was aware they were being monitored but did not know when or in which individual room sampling would occur. Both isolation and non-isolation rooms were sampled. Rooms throughout all areas of the hospital were sampled, including the intensive care units, telemetry, pediatric ward, maternity ward, and surgical wards. Operating rooms were not included.

Sample Processing

Culture method:

Swabs were immediately transported to the central processing lab in Silver Spring, MD. There, each swab was streaked onto a Blood agar (BAP) and a MacConkey (MAC) plate and incubated for 24-48 hours at 35ºC. Gram positive growth on the BAP was further analyzed using rapid tests (Catalase, staph auerex, and tube Coag) followed by the Phoenix (PMIC/ID-107), Bekton Dickenson. All growth on the MAC plate was sent for analysis on the Phoenix (NMIC/ID-133). Any organism that was not definitively identifiable on the Phoenix was analyzed on the Bruker Biotyper MALDI-TOF.

PCR method:

After streaking the BAP and MAC plates, the tip of the same swab was then aseptically removed and submerged in 300ul of sterile water. The tip was then vortexed for 30 seconds, and 20 ul of the resulting supernatant was added to 40ul of Lys and Go solution as described. (ref: Clifford et all, 2012). 2 ul of this solution was used directly for RT-PCR as described. (Clifford et all, 2012) The PCR assay was capable of detecting 1 x 10^2 genome copies from purified genomic DNA. From spiked surfaces in the laboratory, the PCR assay was capable of detecting as low as 3 x 10^3 organisms/ml directly from swab tip without enrichment. Along with MRSA, *E coli, Pseudomonas aeruginosa, and Klebsiella pneumonia*e, the PCR assay detected 94% of all bacterial 16SrRNA sequences published to date in GeneBank (Clifford). The PCR assay did not have primers for detecting *Enterobacter* spp. Although it detected *C. difficile*, we had no ability to culture *C difficile* so we could not confirm positive *C difficile* PCR results with culture.

Genetic Relatedness of MDR-Target Organisms and Correlation of Environmental Bio-Burden with Clinical Infections

To determine genetic relatedness to isolates from clinical infections with MDR-target organisms at FBCH, all *MDR-Klebsiella pneumoniae, E coli, Pseudomonas aeruginosa,* or *Acinetobacter baumannii*, and all MRSA that were isolated from the environment underwent pulsed-field gel electrophoresis using previously described modification of Pulse Net protocols. Logistically, FBCH microbiology department cannot save bacterial isolates from routine clinical infections longer than 7-14 days, so only MDR-isolates could be archived and were therefore available for PFGE comparison.

Using electronic medical records and the laboratory information system, all positive culture results in the microbiology laboratory of the hospital during the entire 17 month study period were data mined to extract all infections caused by the target organisms. The number positive culture with target organisms

from clinical infections in in-patients at the hospital was compared to the number of the times the analogous target organism was detected in the environment by the PCR method and by the culture method.

KEY RESEARCH ACCOMPLISHMENTS

- Protocol written and approved
- New assay developed and validated - manuscript published
- 17 months of surveillance completed with 2833 samples collected and processed
- Thoroughness of cleaning assessed
- Educational intervention provided to FBCH environmental services and infection control staff
- Effectiveness of cleaning assessed
- Unique ACCESS and EXCEL databases created and populated
- Preliminary analysis of all data completed
- Final manuscript drafted
- Interim and final results relayed to FBCH infection control and clinical research department
- Final manuscript drafted
- Study completed

REPORTABLE OUTCOMES

Results

Eighty-three rooms, (7 isolation and 76 non isolation), were sampled twice (before and after terminal cleaning). Forty-two were sampled before the intervention and forty-one were sampled after the intervention. This resulted in 2,833 surfaces being sampled and 2,833 swabs. Of these, 1,367 yielded a positive culture on BAP and 426 on MAC. From these, 520 organisms from 91 different species were identified, with 10 species comprising over two-thirds of all organisms. [**See page 11]** Coagulase neg. *Staphylococcus spp. a*nd *Acinetobacter* spp, were the two most common. 1,226 of 2,833 swabbed surfaces produced a positive 16SrRNA signal on PCR.

***Where were the target organisms found*?**

Target organisms were found in 30 rooms (excluding Enterococcus and Enterobacter) 37 (including *Enterococcus* spp and *Enterobacter* spp) by the culture method and 55 rooms by the PCR method (did not include *Enterobacter* spp and *Enterococcus* spp). [**See pages 12-13]** The maternity ward and the medical wards harbored the most bio-burden of target organisms by both the culture and the PCR method. [**See pages 12-13]** *Acinetobacter baumannii* followed by *Staphylococcus aureus* were the most common culturable target organisms and they were most often cultured from sinks and toilets. [**See pages 14-15**] No target organisms were cultured from room door closers. *Acinetobacter baumannii* and *E. coli* were the most commonly detected target organisms by PCR. *Acinetobacter baumannii* was most often detected on IV poles, toilet rails and tray tables and *E. coli* were most often detected on toilet seats,

toilet handles, and toilet rails. [**See pages 16-17]** No target organisms were detected by PCR from telephones or side rails.

Did the overall recovery of target organisms change after the intervention at the room level?
After the intervention, recovery of target organisms by cultures by room level decreased but not significantly (19 pre; 11 post; P = 0.06). **[See page 12]** That was excluding *Enterobacter* and *Enterococcus* spp because the PCR method did not have the capability to detect those species. When *Enterobacter* and *Enterococcus* were included, the difference was even less significant (22 pre 15 post; P= 0.11). Recovery of target organisms by the PCR method significantly decreased following the intervention (32 pre; 23 post; p=0.04). [**See page 13]**

Discussion point/future analysis: do an analysis considering each target organism separately – i.e. did any individual species group change significantly?

Did the recovery of target organisms by culture change after cleaning at the surface level?
63 surfaces had target organisms by the culture method. [**See page 18**] 45 surfaces with target organisms before room cleaning lacked them after cleaning, while 17 surfaces without culturable target organisms prior to cleaning "acquired" them after room cleaning. This suggests that cleaning may both remove and introduce bacteria to surfaces. Only one surface had target organisms before and after cleaning. **[See page 18**] Overall, cleaned surfaces were less likely to have target organisms than pre-cleaned surfaces **[See page 18]**.

Including *Enteroboacter* and *Enterococcus* species: 82 surfaces had target organisms by culture method; 57 had target organisms before but not after cleaning, while 21 target organism free surfaces before cleaning, acquired a target organism after cleaning. Overall, cleaned surfaces were significantly less likely to have culturable target organisms than pre-cleaned surfaces (P = 0.005). **[See page 19]**

Did the recovery of target organisms by PCR change after cleaning?
107 surfaces had target organisms detectable by the PCR method. 56 surfaces with target organisms before room cleaning lacked them after cleaning, while 46 surfaces without PCR-detectable target organisms prior to cleaning "acquired" them after room cleaning. Five surfaces had target organisms detected by PCR both before and after cleaning. [**See page 20]** Overall, cleaned surfaces were not significantly less likely to have PCR detectable target organisms than pre-cleaned surfaces (P = 0.57) Suggesting cleaning did not remove DNA.

Implication is that target organism DNA even naked or broken (see PNAS paper) is available to cause problems or drive resistance after cleaning.

Did the thoroughness of cleaning of individual surface types as measured by DAZO® pass/failure rates change after the intervention?
Although five surface types showed improved cleaning after the intervention (the call box, room door closer, room sing, sink top and telephone), none of these changes was statically significant. When all

surfaces were combined, the failure rate significantly increased after the intervention (52% failure rate pre and 57% percent failed post (P= 0.04)). [**See page 21]**

Was thoroughness of cleaning (as measured by DAZO pass/failure) correlated with effectiveness of cleaning as measured by overall bio-burden detectable by 16S-PCR, BAP, or MAC?

The effect of cleaning thoroughness on removal of bio-burden (cleaning effectiveness) varied depending on the assay used to measure bio-burden and the surface type. We found no significant difference between 16S-PCR assay results from passed and failed surfaces for any surface type. [**See page 22]**. BAP growth from the room door closer was significantly increased when cleaning was successful (passed). [**See page 23]** MAC growth from telephones significantly decreased when cleaning was successful. [**See page 24]** When all surfaces are combined, the effect of cleaning was not statistically significant. The chance of having a detecting 16S sequences, seeing growth on blood agar and seeing growth on MacConkey agar were similar on passed and failed surfaces. In all three assays, there was a slight increase in positive results when cleaning was successful, but the difference was not significant suggesting that the thoroughness of cleaning at this facility did not affect the level of culture detectable or PCR detectable bio-burden.

Discussion points: Perhaps more thorough cleaning leads to cross contamination.

What cleaning agents and disinfectants were used at the facility?

Note for future analysis: to rule out the possibility that these results reflect assay variation, we have to control for this by first determining if the surface had any detectable bio material to begin with before cleaning. The question is: Does thoroughness of cleaning lead to more contamination or better cleaning? (Check to see if there was bio material before).

Did the effectiveness of cleaning as measured by the culture or PCR method change after the intervention?

The top halves (‘contamination’) of the following tables indicate surfaces that started out without biomaterial as measured by 16S, MAC or BAP (i.e. clean) and ended up 16S, MAC or BAP positive after cleaning. The bottom half (‘cleaning’) indicates surfaces that had biomaterial before cleaning but not after cleaning. Green shading indicates a better outcome after the intervention (either decreased contamination or increased cleaning. Pink shading indicates the opposite. The only individual surfaces that showed a significant change were the toilet rail and tray table, which both had increased bio-burden post intervention as measured by PCR (16S). **[See page 25**] These 16S data suggest contamination worsened after the intervention in that a significantly higher percent of surfaces that were bio material free by 16S became 16S positive after the intervention (p = 0.011). The BAP data also suggests contamination increased after intervention, in that combining all surfaces, the ratio of those that went from 16S negative to 16S positive was significantly higher after the intervention. [**See page 26]** The MAC data, in contrast, suggest outcomes improved a bit after the intervention but neither individual surfaces or all surfaces combined showed statistically significant changes. [**See page 27]** In summary, the intervention produced few significant differences in cleaning effectiveness. PCR method derived

data and BAP data indicates outcomes worsened overall, while MAC-derived data suggest outcomes improved overall.

Discussion: were the staff "scrubbing harder" and moving biomaterial around?

Was environmental contamination by culture or PCR correlated with clinical cultures?
Infection rates over the study period are plotted with environmental rates by the PCR method and by the culture method in. [**See pages 28-29**] There were no infections caused by *Acinetobacter baumannii* or *C. difficile* over the study period. The most common target organism infection was *Staphylococcus aureus* (n=77), followed by *E coli* (56), *Klebsiella pneumoniae* (28), and *Pseudomonas aeruginosa* (11). There was a strong positive correlation between in-patient infections and the detection of *E. coli* in the environment by the PCR method (P= 0.0004). [**See page 30**] No other correlation between infections and environmental presence of other target organism was statistically significant by either the culture or PCR method. [**See page 31]**

Future analysis: add Enterobacter spp culture and infection data

Finishing PFGEs for mrsa

CONCLUSION
Implication is that target organism DNA even naked or broken (see PNAS paper) is available to cause problems or drive resistance after cleaning.

Species n= 91	**Total (%)**
	520
Coagulase negative *Staphylococcus*	103 (25)
Pantoea agglomerans	42 (8)
Micrococcus luteus	36 (7)
Pseudomonas putida	32 (6)
Acinetobacter baumannii and complex	30 (6)
Acinetobacter lwoffi	27 (5)
Enterobacter cloacae	15 (3)
Staphylococcus aureus	14 (3)
Staphylococcus saprophyticus	14 (3)
Enterococcus (faecium and faecalis)	11 (2)
The remaining 11 species each comprised less than 2% of total	169 (32)

Group	preInt	postInt	total
Icu	5	7	12
maternity ward	8	8	16
medical telemetry	9	9	18
medical ward	7	8	15
pediatric ward	6	3	9
surgical ward	7	6	13
total	42	41	83

group	preIntPcr	postIntPcr	totalPcr
icu	4	5	9
maternity ward	7	6	13
medical telemetry	5	3	8
medical ward	6	5	11
pediatric ward	5	3	8
surgical ward	5	1	6
total	32	23	55

group	preIntCul	postIntCul	totalCul
icu	3	1	4
maternity ward	4	3	7
medical telemetry	2	1	3
medical ward	5	3	8
pediatric ward	3	2	5
surgical ward	2	1	3
total	19	11	30

culture

	positive	negative			
Before Intervention	19	23	42	Fisher's exact test p-value	
After Intervention	11	30	41	two-tailed	0.110234
	30	53		one-tailed	0.064293

species PCR

	positive	negative			
Before Intervention	32	10	42	two-tailed	0.065478
After Intervention	23	18	41	one-tailed	0.043855

Room Summary Statistics

group	preInt	postInt	total
icu	5	7	12
maternity ward	8	8	16
medical telemetry	9	9	18
medical ward	7	8	15
pediatric ward	6	3	9
surgical ward	7	6	13
total	42	41	83

Species-specific PCR

group	preIntPcr	postIntPcr	totalPcr
icu	4	5	9
maternity ward	7	6	13
medical telemetry	5	3	8
medical ward	6	5	11
pediatric ward	5	3	8
surgical ward	5	1	6
total	32	23	55

Target Organism Culture

group	preIntCul	postIntCul	totalCul
icu	4	2	6
maternity ward	5	5	10
medical telemetry	3	2	5
medical ward	5	3	8
pediatric ward	3	2	5
surgical ward	2	1	3
total	22	15	37

culture

	positive	negative			
Before Intervention	22	20	42	Fisher's exact test p-value two-tailed	0.186970
After Intervention	15	26	41	one-tailed	0.109870
	37	46			

species-specific PCR

	positive	negative			
Before Intervention	32	10	42	Fisher's exact test p-value two-tailed	0.065478
After Intervention	23	18	41	one-tailed	0.043855
	55	28			

Before Cleaning

surface	Acb	Eco	Enterob	Kpn	Psa	Staph	Enteroc
bathroom door closer	1	1	0	0	0	1	0
bathroom lightswitch	0	0	0	0	0	1	0
bedpan cleaner	0	0	0	0	0	0	1
bedside table	1	0	0	0	0	0	0
call box	2	0	0	0	0	0	0
iv pole	1	0	0	0	0	1	1
room chair	1	0	0	0	0	1	0
room lightswitch	1	0	0	0	0	0	0
room sink	2	0	2	0	0	1	0
side rail	1	0	0	0	0	2	1
sink top	3	1	6	3	4	3	0
telephone	1	0	0	1	0	1	0
toilet handle	1	0	1	0	0	0	3
toilet rail	4	0	1	0	0	0	0
toilet seat	2	4	2	0	0	1	0
tray table	1	0	0	0	0	0	0
total	22	6	12	4	4	12	6

After Cleaning

surface	Acb	Eco	Enterob	Kpn	Psa	Staph	Enteroc
bathroom door closer	0	0	0	0	0	0	1
bathroom lightswitch	0	0	0	0	0	0	0
bedpan cleaner	0	0	0	0	0	0	1
bedside table	0	0	0	0	0	0	0
call box	1	0	0	0	0	1	0
iv pole	1	0	0	0	0	0	0
room chair	0	0	0	1	0	0	0
room lightswitch	1	0	0	0	0	0	0
room sink	3	0	2	0	1	0	0
side rail	0	0	0	0	0	0	0
sink top	2	0	1	1	0	0	0
telephone	0	0	0	0	0	0	0
toilet handle	0	0	0	0	0	0	1
toilet rail	0	0	0	0	0	2	0
toilet seat	0	3	0	0	0	1	0
tray table	0	0	0	0	0	0	1
total	8	3	3	2	1	4	4

Before or After Cleaning

surface	Acb	Eco	Enterob	Kpn	Psa	Staph	Enteroc
bathroom door closer	1	1	0	0	0	1	1
bathroom lightswitch	0	0	0	0	0	1	0
bedpan cleaner	0	0	0	0	0	0	2
bedside table	1	0	0	0	0	0	0
call box	3	0	0	0	0	1	0
iv pole	2	0	0	0	0	1	1
room chair	1	0	0	1	0	1	0

room lightswitch	2	0	0	0	0	0	0
room sink	4	0	3	0	1	1	0
side rail	1	0	0	0	0	2	1
sink top	5	1	6	4	4	3	0
telephone	1	0	0	1	0	1	0
toilet handle	1	0	1	0	0	0	3
toilet rail	4	0	1	0	0	2	0
toilet seat	2	7	2	0	0	2	0
tray table	1	0	0	0	0	0	1
total	29	9	13	6	5	16	9

before cleaning

surface	acb	cdiff	eco	kpn	psa	staph	
bathroom door closer	1	0	1	0	0	1	
bathroom lightswitch	1	0	0	1	0	0	
bedpan cleaner	1	0	4	0	0	0	
bedside table	3	0	0	0	0	0	
call box	1	0	0	1	0	0	
iv pole	4	1	2	1	0	0	
room chair	1	0	0	1	0	1	
room door closer	0	0	0	0	0	0	
room lightswitch	1	0	0	1	0	0	
room sink	3	0	1	2	2	0	
sink top	3	0	2	2	4	1	
toilet handle	2	0	0	0	0	0	
toilet rail	4	0	1	0	0	0	
toilet seat	1	0	5	0	0	0	
tray table	3	0	1	1	0	0	
total	29	1	17	10	6	3	66

after cleaning

surface	acb	cdiff	eco	kpn	psa	staph	
bathroom door closer	0	0	0	0	0	0	
bathroom lightswitch	0	0	0	0	0	0	
bedpan cleaner	0	0	2	0	0	2	
bedside table	1	0	0	1	0	1	
call box	0	0	0	0	0	0	
iv pole	3	0	0	0	0	0	
room chair	2	0	1	1	0	1	
room door closer	1	0	0	0	0	0	
room lightswitch	1	0	1	0	0	0	
room sink	3	0	0	1	1	2	
sink top	1	0	3	0	0	1	
toilet handle	0	0	2	0	0	2	
toilet rail	3	0	4	2	0	1	
toilet seat	1	0	2	0	0	0	
tray table	4	0	1	0	0	0	
total	20	0	16	5	1	10	52

Positive species-specific PCR result before and/or after cleaning

surface	acb	cdiff	eco	kpn	psa	staph
bathroom door closer	1	0	1	0	0	1
bathroom lightswitch	1	0	0	1	0	0
bedpan cleaner	1	0	4	0	0	2
bedside table	4	0	0	1	0	1
call box	1	0	0	1	0	0
iv pole	7	1	2	1	0	0
room chair	3	0	1	2	0	2
room door closer	1	0	0	0	0	0
room lightswitch	2	0	1	1	0	0
room sink	5	0	1	3	3	2
sink top	4	0	5	2	4	2
toilet handle	2	0	2	0	0	2
toilet rail	7	0	5	2	0	1
toilet seat	2	0	7	0	0	0
tray table	7	0	2	1	0	0
total	48	1	31	15	7	13

Before or After Cleaning

surface	n=	percent
bedpan cleaner	0	0.0
bathroom lightswitch	1	1.6
bedside table	1	1.6
toilet handle	1	1.6
tray table	1	1.6
room lightswitch	2	3.2
telephone	3	4.8
bathroom door closer	3	4.8
iv pole	3	4.8
room chair	3	4.8
side rail	3	4.8
call box	4	6.3
room sink	6	9.5
toilet rail	6	9.5
toilet seat	10	15.9
sink top	16	25.4
total_all	63	100.0

group	n=	percent
before cleaning	45	71.4
after cleaning	17	27.0
before and after	1	1.6
total	63	100.0

Before Cleaning

surface	n=	percent
sink top	13	28.9
bathroom door closer	3	6.7
side rail	3	6.7
telephone	3	6.7
toilet rail	4	8.9
toilet seat	6	13.3
bathroom lightswitch	1	2.2
bedside table	1	2.2
iv pole	2	4.4
room chair	2	4.4
toilet handle	1	2.2
tray table	1	2.2
bedpan cleaner	0	0.0
call box	2	4.4
room lightswitch	1	2.2
room sink	2	4.4
total_before	45	100.0

After Cleaning

surface	n=	percent
sink top	3	17.6
bathroom door closer	0	0.0
side rail	0	0.0
telephone	0	0.0
toilet rail	2	11.8
toilet seat	4	23.5
bathroom lightswitch	0	0.0
bedside table	0	0.0
iv pole	1	5.9
room chair	1	5.9
toilet handle	0	0.0
tray table	0	0.0
bedpan cleaner	0	0.0
call box	2	11.8
room lightswitch	1	5.9
room sink	3	17.6
total_after	17	100.0

Before or After Cleaning

surface	n=	percent
bathroom lightswitch	1	1.2
bedside table	1	1.2
bedpan cleaner	2	2.4
room lightswitch	2	2.4
tray table	2	2.4
room chair	3	3.7
telephone	3	3.7
bathroom door closer	4	4.9
call box	4	4.9
iv pole	4	4.9
side rail	4	4.9
toilet handle	5	6.1
toilet rail	7	8.5
room sink	9	11.0
toilet seat	10	12.2
sink top	21	25.6
total_all	82	100.0

group	n=	percent
before cleaning	57	69.5
after cleaning	21	25.6
before and after	4	4.9
total	82	100.0

Before Cleaning

surface	n=	percent
sink top	18	29.5
side rail	4	6.6
telephone	3	4.9
toilet handle	5	8.2
bathroom lightswitch	1	1.6
bedside table	1	1.6
bathroom door closer	3	4.9
iv pole	3	4.9
toilet rail	5	8.2
room chair	2	3.3
bedpan cleaner	1	1.6
room lightswitch	1	1.6
tray table	1	1.6
call box	2	3.3
toilet seat	6	9.8
room sink	5	8.2
total_before	61	100.0

After Cleaning

surface	n=	percent
sink top	4	16.0
side rail	0	0.0
telephone	0	0.0
toilet handle	1	4.0
bathroom lightswitch	0	0.0
bedside table	0	0.0
bathroom door closer	1	4.0
iv pole	1	4.0
toilet rail	2	8.0
room chair	1	4.0
bedpan cleaner	1	4.0
room lightswitch	1	4.0
tray table	1	4.0
call box	2	8.0
toilet seat	4	16.0
room sink	6	24.0
total_after	25	100.0

before or after cleaning

surface	n=	percent
room door closer	1	0.9
bathroom lightswitch	2	1.9
call box	2	1.9
bathroom door closer	3	2.8
room lightswitch	3	2.8
bedside table	6	5.6
toilet handle	6	5.6
bedpan cleaner	7	6.5
room chair	7	6.5
toilet seat	9	8.4
iv pole	10	9.3
tray table	10	9.3
room sink	13	12.1
sink top	14	13.1
toilet rail	14	13.1
total	107	100.0

group	n=	percent
before cleaning	56	52.3
after cleaning	46	43.0
before and after	5	4.7
total	107	100.0

before cleaning

surface	n=	percent
sink top	9	16.1
iv pole	7	12.5
bathroom door closer	3	5.4
toilet seat	6	10.7
bathroom lightswitch	2	3.6
call box	2	3.6
bedpan cleaner	3	5.4
bedside table	3	5.4
room sink	6	10.7
tray table	5	8.9
room chair	3	5.4
room door closer	0	0.0
room lightswitch	1	1.8
toilet handle	2	3.6
toilet rail	4	7.1
total	56	100.0

after cleaning

surface	n=	percent
sink top	4	8.7
iv pole	3	6.5
bathroom door closer	0	0.0
toilet seat	3	6.5
bathroom lightswitch	0	0.0
call box	0	0.0
bedpan cleaner	2	4.3
bedside table	3	6.5
room sink	6	13.0
tray table	5	10.9
room chair	4	8.7
room door closer	1	2.2
room lightswitch	2	4.3
toilet handle	4	8.7
toilet rail	9	19.6
total	46	100.0

surface	pre_pass	pre_fail	pre_fail_pct	pst_pass	pst_fail	pst_fail_pct	p_value	improved
tray table	39	3	7.14	32	8	20.00	0.1119	
toilet seat	38	3	7.32	36	5	12.20	0.7123	
room chair	24	9	**27.27**	14	27	**65.85**	0.0012	
bathroom door closer	25	17	40.48	23	18	43.90	0.8257	
iv pole	17	12	41.38	18	13	41.94	1.0000	
telephone	23	17	42.50	26	15	36.59	0.6528	
bedside table	20	17	45.95	18	23	56.10	0.4965	
sink top	21	21	50.00	22	19	46.34	0.8272	
bedpan cleaner	18	23	56.10	14	27	65.85	0.4974	
call box	15	26	63.41	20	20	50.00	0.2658	
side rail	14	25	64.10	11	28	71.79	0.6280	
bathroom lightswitch	15	27	64.29	7	34	82.93	0.0811	
toilet handle	14	27	65.85	12	29	70.73	0.8127	
room door closer	12	30	71.43	12	29	70.73	1.0000	
room sink	9	24	72.73	14	27	65.85	0.6170	
toilet rail	10	32	76.19	9	32	78.05	1.0000	
room lightswitch	5	28	84.85	3	38	92.68	0.4538	
total	319	341	**51.67**	291	392	**57.39**	0.0373	

surface	PassPcr+	PassPcr-	PassPctPcr+	FailPcr+	FailPcr-	FailPctPcr+	p_value
bathroom door closer	17	31	35.42	9	26	25.71	0.4729
bathroom lightswitch	7	15	31.82	11	50	18.03	0.2288
bedpan cleaner	7	25	21.88	16	34	32.00	0.4504
bedside table	22	16	57.89	17	23	42.50	0.2573
call box	10	25	28.57	13	33	28.26	1.0000
iv pole	15	22	40.54	15	10	60.00	0.1954
room chair	19	19	50.00	14	22	38.89	0.3599
room door closer	8	16	33.33	19	40	32.20	1.0000
room lightswitch	2	6	25.00	15	51	22.73	1.0000
room sink	14	9	60.87	28	23	54.90	0.8004
side rail	6	19	24.00	9	44	16.98	0.5421
sink top	25	18	58.14	18	22	45.00	0.2752
telephone	16	33	32.65	15	17	46.88	0.2450
toilet handle	6	20	23.08	23	33	41.07	0.1404
toilet rail	10	9	52.63	43	21	67.19	0.2835
toilet seat	22	52	29.73	3	5	37.50	0.6946
tray table	35	36	49.30	3	8	27.27	0.2085
Total	241	371	39.38	271	462	36.97	0.3676

Univeral bacterial 16S PCR assay results: compare Passed and Failed cleaning, measured by DAZO removal

surface	PassGrowth	PassNoGrowth	PassPctGrowth	FailGrowth	FailNoGrowth	FailPctGrowth	p_value
bathroom door closer	10	38	20.83	13	22	37.14	0.1370
bathroom lightswitch	5	17	22.73	9	52	14.75	0.5071
bedpan cleaner	4	28	12.50	9	41	18.00	0.5548
bedside table	25	13	65.79	21	19	52.50	0.2579
call box	10	25	28.57	22	24	47.83	0.1088
iv pole	15	22	40.54	13	12	52.00	0.4405
room chair	19	19	50.00	19	17	52.78	0.8208
room door closer	14	10	58.33	11	48	18.64	0.0011
room lightswitch	0	8	0.00	12	54	18.18	0.3392
room sink	13	10	56.52	27	24	52.94	0.8062
side rail	1	24	4.00	8	45	15.09	0.2578
sink top	29	14	67.44	24	16	60.00	0.5023
telephone	25	24	51.02	18	14	56.25	0.6573
toilet handle	4	22	15.38	11	45	19.64	0.7650
toilet rail	13	6	68.42	52	12	81.25	0.3404
toilet seat	28	46	37.84	4	4	50.00	0.7051
tray table	41	30	57.75	4	7	36.36	0.2100
Total	256	356	41.83	277	456	37.79	0.1455

Growth on blood agar: compare Passed and Failed cleaning, measured by DAZO removal

surface	PassGrowth	PassNoGrowth	PassPctGrowth	FailGrowth	FailNoGrowth	FailPctGrowth	p_value
bathroom door closer	1	47	2.08	1	34	2.86	1.0000
bathroom lightswitch	2	20	9.09	4	57	6.56	0.6532
bedpan cleaner	1	31	3.13	2	48	4.00	1.0000
bedside table	5	33	13.16	5	35	12.50	1.0000
call box	2	33	5.71	3	43	6.52	1.0000
iv pole	4	33	10.81	1	24	4.00	0.6398
room chair	5	33	13.16	5	31	13.89	1.0000
room door closer	0	24	0.00	1	58	1.69	1.0000
room lightswitch	0	8	0.00	2	64	3.03	1.0000
room sink	7	16	30.43	15	36	29.41	1.0000
side rail	0	25	0.00	1	52	1.89	1.0000
sink top	19	24	44.19	13	27	32.50	0.3672
telephone	3	46	6.12	7	25	21.88	0.0447
toilet handle	2	24	7.69	1	55	1.79	0.2349
toilet rail	2	17	10.53	15	49	23.44	0.3352
toilet seat	6	68	8.11	1	7	12.50	0.5266
tray table	15	56	21.13	0	11	0.00	0.2018
Total	74	538	12.09	77	656	10.50	0.3861

Growth on MacConkey agar: compare Passed and Failed cleaning, measured by DAZO removal

outcome	surface	prMP	prMM	poMP	poMM	pval	prPct	poPct	delta
contamination	bathroom door closer	5	21	10	21	0.3681	19.23	32.26	13.03
contamination	bathroom lightswitch	7	24	5	23	0.7522	22.58	17.86	-4.72
contamination	bedpan cleaner	2	23	6	20	0.2485	8.00	23.08	15.08
contamination	bedside table	1	11	6	11	0.1872	8.33	35.29	26.96
contamination	call box	4	20	8	20	0.3456	16.67	28.57	11.90
contamination	iv pole	4	8	6	11	1.0000	33.33	35.29	1.96
contamination	room chair	6	8	8	17	0.5119	42.86	32.00	-10.86
contamination	room door closer	5	17	8	19	0.7477	22.73	29.63	6.90
contamination	room lightswitch	2	19	8	20	0.1554	9.52	28.57	19.05
contamination	room sink	5	5	7	12	0.6942	50.00	36.84	-13.16
contamination	side rail	2	27	5	21	0.2363	6.90	19.23	12.33
contamination	sink top	5	6	8	9	1.0000	45.45	47.06	1.60
contamination	telephone	3	11	4	15	1.0000	21.43	21.05	-0.38
contamination	toilet handle	5	20	8	16	0.3451	20.00	33.33	13.33
contamination	toilet rail	1	10	9	7	0.0183	9.09	56.25	47.16
contamination	toilet seat	3	15	7	14	0.2898	16.67	33.33	16.67
contamination	tray table	5	14	7	13	0.7311	26.32	35.00	8.68
contamination	Total	65	259	120	269	0.0011	20.06	30.85	10.79

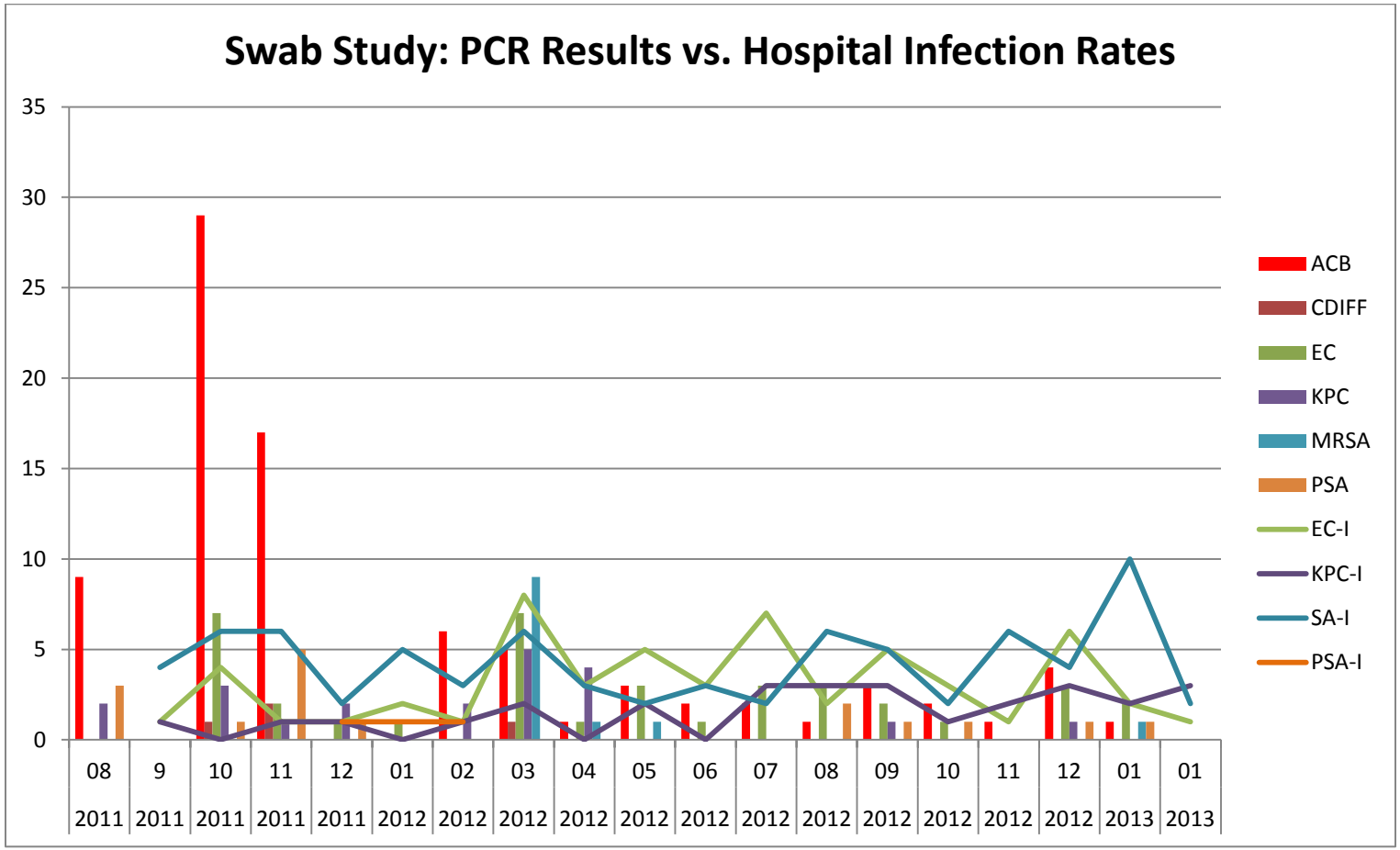
outcome	surface	prPP	prPM	poPP	poPM	pval	prPct	poPct	delta
cleaning	bathroom door closer	7	9	4	6	1.0000	43.75	40.00	-3.75
cleaning	bathroom lightswitch	4	7	2	11	0.3572	36.36	15.38	-20.98
cleaning	bedpan cleaner	7	9	8	7	0.7244	43.75	53.33	9.58
cleaning	bedside table	17	8	15	9	0.7688	68.00	62.50	-5.50
cleaning	call box	8	9	3	9	0.2732	47.06	25.00	-22.06
cleaning	iv pole	10	7	10	4	0.7074	58.82	71.43	12.61
cleaning	room chair	12	7	7	9	0.3179	63.16	43.75	-19.41
cleaning	room door closer	10	10	4	10	0.2955	50.00	28.57	-21.43
cleaning	room lightswitch	2	10	5	8	0.3783	16.67	38.46	21.79
cleaning	room sink	15	8	15	7	1.0000	65.22	68.18	2.96
cleaning	side rail	4	6	4	9	0.6850	40.00	30.77	-9.23
cleaning	sink top	19	12	11	13	0.2864	61.29	45.83	-15.46
cleaning	telephone	12	14	12	10	0.7725	46.15	54.55	8.39
cleaning	toilet handle	6	10	10	7	0.3028	37.50	58.82	21.32
cleaning	toilet rail	24	7	19	6	1.0000	77.42	76.00	-1.42
cleaning	toilet seat	10	13	5	15	0.3363	43.48	25.00	-18.48
cleaning	tray table	18	5	8	12	0.0143	78.26	40.00	-38.26
cleaning	Total	185	151	142	152	0.0939	55.06	48.30	-6.76

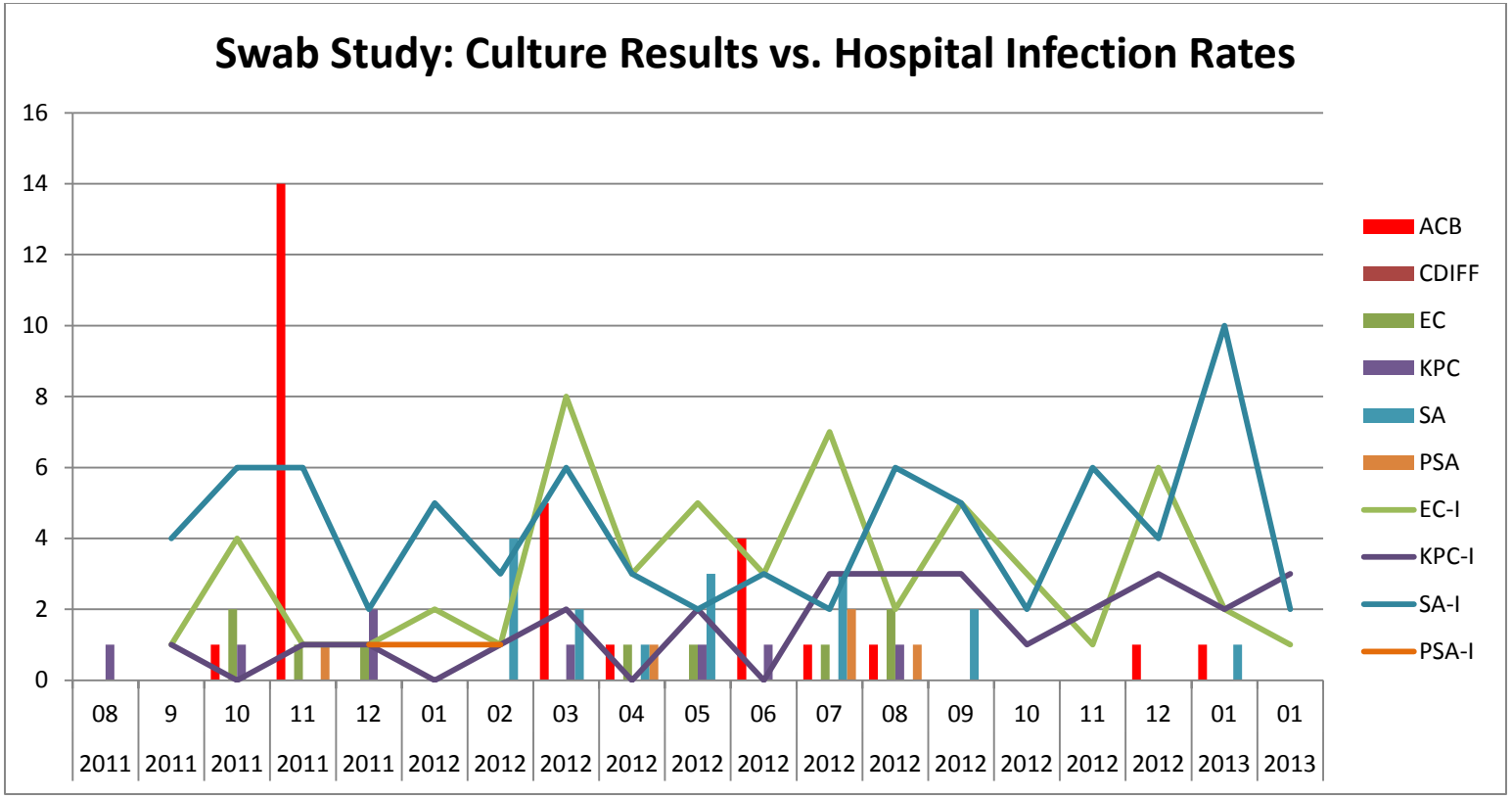
outcome	surface	prMP	prMM	poMP	poMM	pval	prPct	poPct	delta
contamination	bathroom door closer	4	21	7	22	0.5166	16.00	24.14	8.14
contamination	bathroom lightswitch	5	29	3	26	0.7156	14.71	10.34	-4.36
contamination	bedpan cleaner	4	24	4	24	1.0000	14.29	14.29	0.00
contamination	bedside table	3	2	2	6	0.2929	60.00	25.00	-35.00
contamination	call box	10	16	8	12	1.0000	38.46	40.00	1.54
contamination	iv pole	2	7	5	3	0.1534	22.22	62.50	40.28
contamination	room chair	4	6	11	10	0.7043	40.00	52.38	12.38
contamination	room door closer	5	21	4	20	1.0000	19.23	16.67	-2.56
contamination	room lightswitch	3	24	5	21	0.4672	11.11	19.23	8.12
contamination	room sink	2	6	7	6	0.3666	25.00	53.85	28.85
contamination	side rail	1	32	3	22	0.3052	3.03	12.00	8.97
contamination	sink top	2	1	5	1	1.0000	66.67	83.33	16.67
contamination	telephone	3	9	6	9	0.6828	25.00	40.00	15.00
contamination	toilet handle	3	22	2	23	1.0000	12.00	8.00	-4.00
contamination	toilet rail	1	0	2	3	1.0000	100.00	40.00	-60.00
contamination	toilet seat	2	9	3	8	1.0000	18.18	27.27	9.09
contamination	tray table	3	7	6	5	0.3870	30.00	54.55	24.55
contamination	Total	57	236	83	221	0.0263	19.45	27.30	7.85

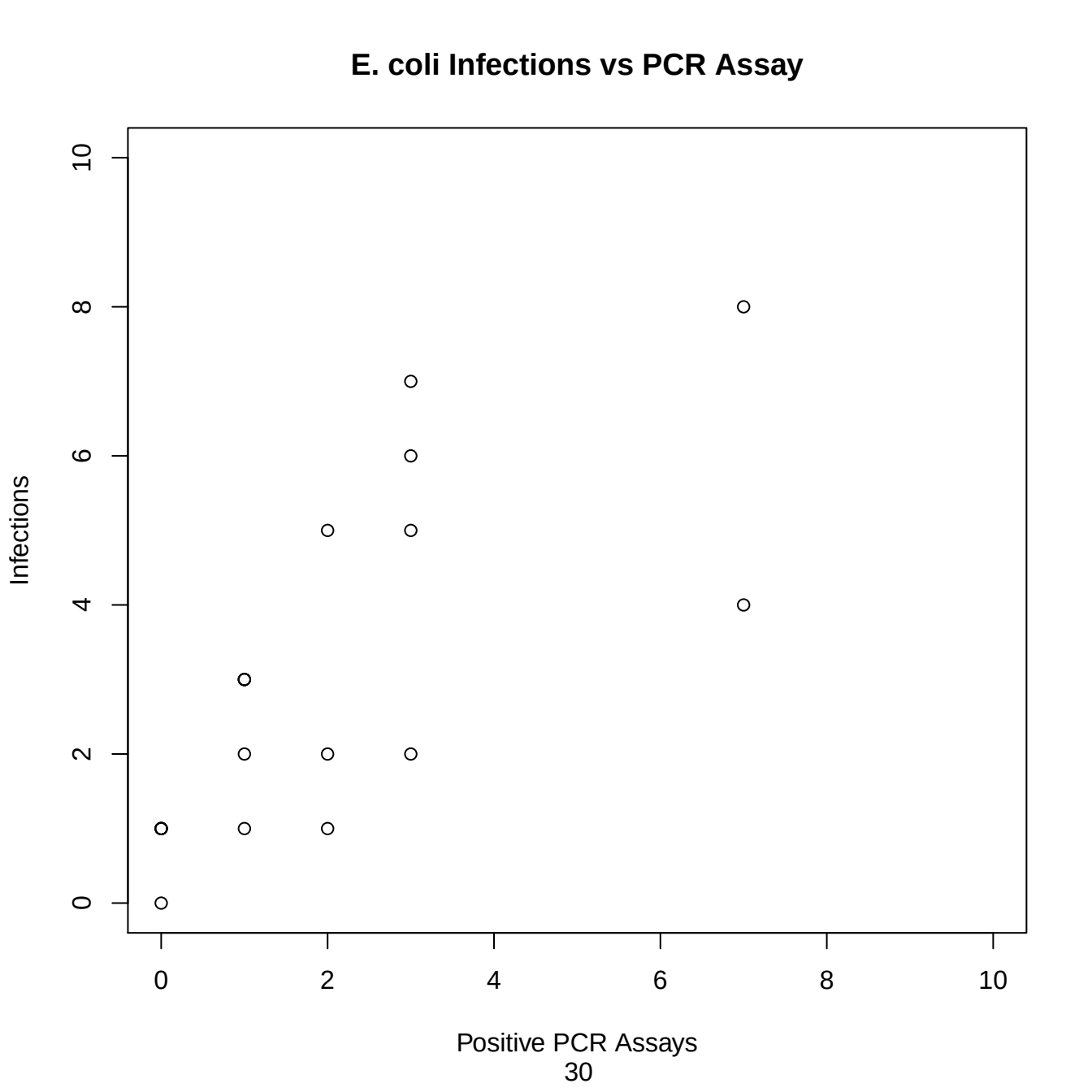
outcome	surface	prPP	prPM	poPP	poPM	pval	prPct	poPct	delta
cleaning	bathroom door closer	7	10	5	7	1.0000	58.82	58.33	-0.49
cleaning	bathroom lightswitch	3	5	3	9	0.6424	62.50	75.00	12.50
cleaning	bedpan cleaner	2	11	3	10	1.0000	84.62	76.92	-7.69
cleaning	bedside table	21	11	20	13	0.7984	34.38	39.39	5.02
cleaning	call box	6	9	8	12	1.0000	60.00	60.00	0.00
cleaning	iv pole	10	10	11	12	1.0000	50.00	52.17	2.17
cleaning	room chair	14	9	9	11	0.3662	39.13	55.00	15.87
cleaning	room door closer	10	6	6	11	0.1694	37.50	64.71	27.21
cleaning	room lightswitch	1	5	3	12	1.0000	83.33	80.00	-3.33
cleaning	room sink	15	10	16	12	1.0000	40.00	42.86	2.86
cleaning	side rail	1	5	4	10	1.0000	83.33	71.43	-11.90
cleaning	sink top	25	14	21	14	0.8118	35.90	40.00	4.10
cleaning	telephone	17	11	17	9	0.7831	39.29	34.62	-4.67
cleaning	toilet handle	5	11	5	11	1.0000	68.75	68.75	0.00
cleaning	toilet rail	34	7	28	8	0.5805	17.07	22.22	5.15
cleaning	toilet seat	12	18	15	15	0.6042	60.00	50.00	-10.00
cleaning	tray table	17	15	19	10	0.4355	46.88	34.48	-12.39
cleaning	Total	200	167	193	186	0.3410	45.50	49.08	3.57

outcome	surface	prMP	prMM	poMP	poMM	pval	prPct	poPct	delta
contamination	bathroom door closer	1	36	1	37	1.0000	2.70	2.63	-0.07
contamination	bathroom lightswitch	5	37	1	40	0.2016	11.90	2.44	-9.47
contamination	bedpan cleaner	2	37	1	40	0.6108	5.13	2.44	-2.69
contamination	bedside table	1	23	3	25	0.6146	4.17	10.71	6.55
contamination	call box	2	34	2	35	1.0000	5.56	5.41	-0.15
contamination	iv pole	2	24	2	24	1.0000	7.69	7.69	0.00
contamination	room chair	4	22	2	34	0.2272	15.38	5.56	-9.83
contamination	room door closer	1	39	0	39	1.0000	2.50	0.00	-2.50
contamination	room lightswitch	1	31	1	38	1.0000	3.13	2.56	-0.56
contamination	room sink	3	18	6	22	0.7137	14.29	21.43	7.14
contamination	side rail	1	38	0	37	1.0000	2.56	0.00	-2.56
contamination	sink top	7	9	5	16	0.2913	43.75	23.81	-19.94
contamination	telephone	4	26	6	30	0.7454	13.33	16.67	3.33
contamination	toilet handle	3	34	0	40	0.1062	8.11	0.00	-8.11
contamination	toilet rail	5	27	5	25	1.0000	15.63	16.67	1.04
contamination	toilet seat	3	29	2	29	1.0000	9.38	6.45	-2.92
contamination	tray table	4	28	4	25	1.0000	12.50	13.79	1.29
contamination	Total	49	492	41	536	0.2713	9.06	7.11	-1.95

outcome	surface	prPP	prPM	poPP	poPM	pval	prPct	poPct	delta
cleaning	bathroom door closer	0	5	0	3	1.0000	100.00	100.00	0.00
cleaning	bedside table	3	10	3	10	1.0000	76.92	76.92	0.00
cleaning	call box	1	4	0	3	1.0000	80.00	100.00	20.00
cleaning	iv pole	1	2	0	5	0.3750	66.67	100.00	33.33
cleaning	room chair	4	3	0	5	0.0808	42.86	100.00	57.14
cleaning	room door closer	0	2	0	2	1.0000	100.00	100.00	0.00
cleaning	room lightswitch	0	1	0	2	1.0000	100.00	100.00	0.00
cleaning	room sink	7	5	6	7	0.6951	41.67	53.85	12.18
cleaning	sink top	11	15	9	11	1.0000	57.69	55.00	-2.69
cleaning	telephone	0	10	0	5	1.0000	100.00	100.00	0.00
cleaning	toilet handle	0	4	0	1	1.0000	100.00	100.00	0.00
cleaning	toilet rail	4	6	3	8	0.6594	60.00	72.73	12.73
cleaning	toilet seat	2	7	0	10	0.2105	77.78	100.00	22.22
cleaning	tray table	4	6	3	8	0.6594	60.00	72.73	12.73
cleaning	Total	37	82	24	82	0.1775	68.91	77.36	8.45


Swab Study: PCR Results vs. Hospital Infection Rates
35
30
25
20
15
10
5
0
08 2011
9 2011
10 2011
11 2011
12 2011
01 2012
02 2012
03 2012
04 2012
05 2012
06 2012
07 2012
08 2012
09 2012
10 2012
11 2012
12 2012
01 2013
01 2013
ACB
CDIFF
EC
KPC
MRSA
PSA
EC-I
KPC-I
SA-I
PSA-I


Swab Study: Culture Results vs. Hospital Infection Rates
16
14
12
10
8
6
4
2
0
08 2011
9 2011
10 2011
11 2011
12 2011
01 2012
02 2012
03 2012
04 2012
05 2012
06 2012
07 2012
08 2012
09 2012
10 2012
11 2012
12 2012
01 2013
01 2013
ACB
CDIFF
EC
KPC
SA
PSA
EC-I
KPC-I
SA-I
PSA-I


E. coli Infections vs PCR Assay
Infections
0
2
4
6
8
10
Positive PCR Assays
30

A. baumannii

pcr vs infections correlation = NA
pcr vs infections p-value = NA
culture vs infections correlation = NA
culture vs infections p-value = NA

C. difficile

pcr vs infections correlation = NA
pcr vs infections p-value = NA
culture vs infections correlation = NA
culture vs infections p-value = NA

E. coli

pcr vs infections correlation = 0.727055
pcr vs infections p-value = 0.0004206506
culture vs infections correlation = 0.08588663
culture vs infections p-value = 0.7266371

K. pneumoniae

pcr vs infections correlation = -0.3093874
pcr vs infections p-value = 0.1974198
culture vs infections correlation = -0.2177919
culture vs infections p-value = 0.3704109

S. aureus

pcr vs infections correlation = 0.2366371
pcr vs infections p-value = 0.3293622
culture vs infections correlation = -0.1073901
culture vs infections p-value = 0.6616815

P. aeruginosa

pcr vs infections correlation = -0.3189535
pcr vs infections p-value = 0.1831954
culture vs infections correlation = -0.1055921
culture vs infections p-value = 0.6670323